# A look at Time of Flight for E907

Tim Bergfeld
U. of S. Carolina

- Monte Carlo Setup
- Position and Size
- Timing Resolution
- Segmentation
- A brief look at cost



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# The Justification for TOF

The dE/dx measurements of tracks from the TPC will give Particle ID up to about 0.9 GeV/c

The Cherenkov detector thresholds are 2.5 GeV/c for pions, 7.5 GeV/c for Kaons and 17.5 GeV/c for protons

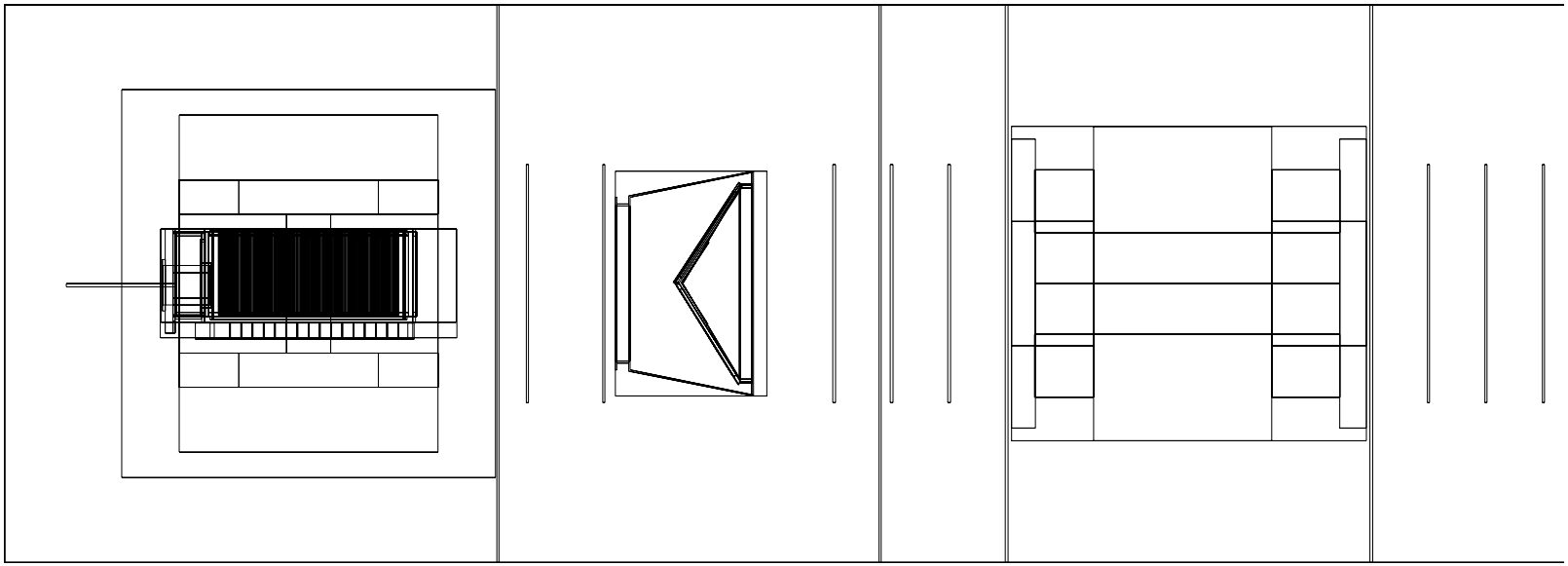
Leaves a range of momentum between 0.7 GeV/c and 2.7 GeV/c with no Particle ID

This is the job for the TOF detector

Pion/Kaon separation for tracks between 0.7 GeV/c and 2.7 GeV/c, and Kaon/proton separation at higher momenta

# Monte Carlo Setup

Use the GEANT Monte Carlo discussed before:



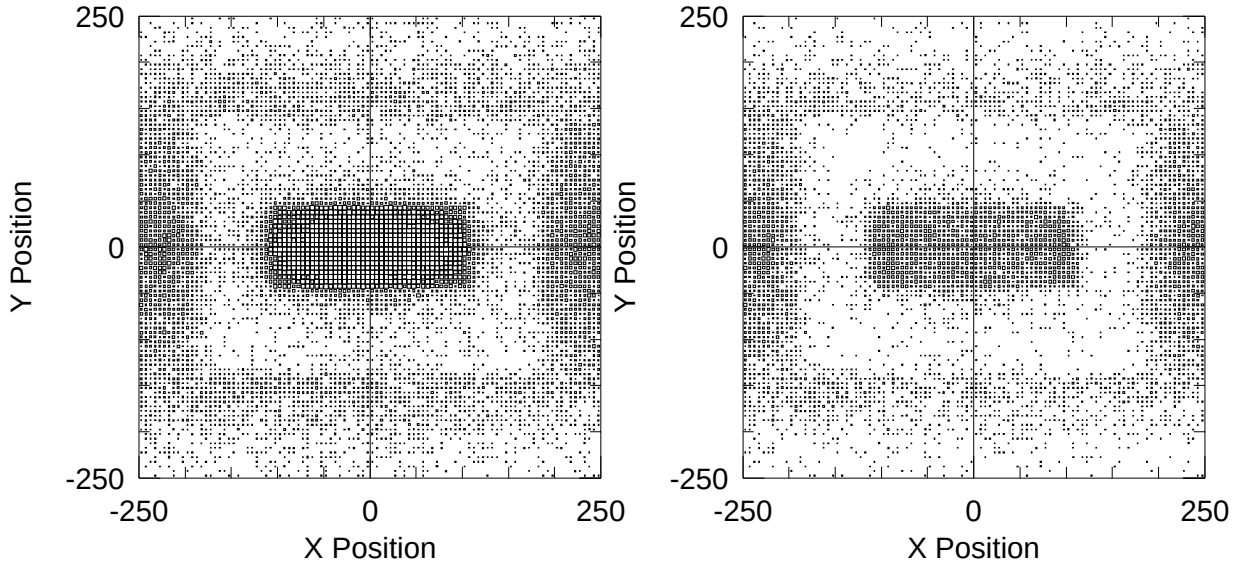
Add full planes of TOF counters which stretch over the entire master volume in X and Y. These are placed after both magnets and before the second magnet. Removed chambers 6 and 7 which were around ROSY magnet. As well as a TOF counter at− 251 cm in Z.

Use MINOS Target with 120GeV/c protons as the beam
(94 cm thick carbon target)

# Location for TOF

Clearly as far as possible from the interaction gives the best time separation for the K's and p's.

Need to worry about second magnet blocking particles.
When TPLB magnet was in the Monte Carlo:



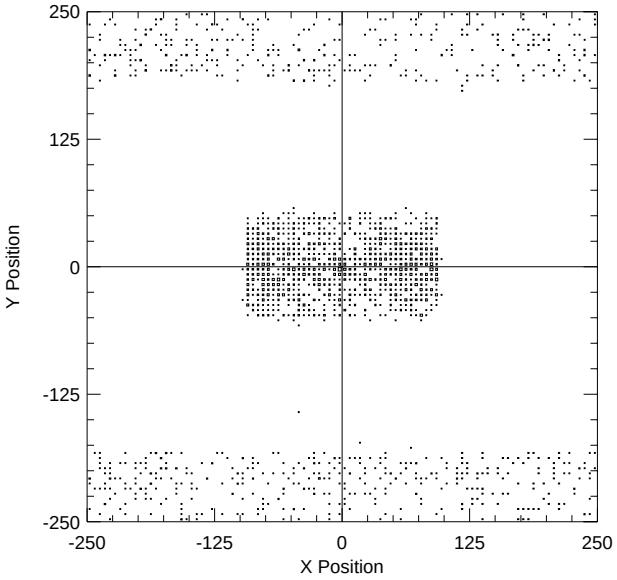

All Tracks

TOF momentum Tracks

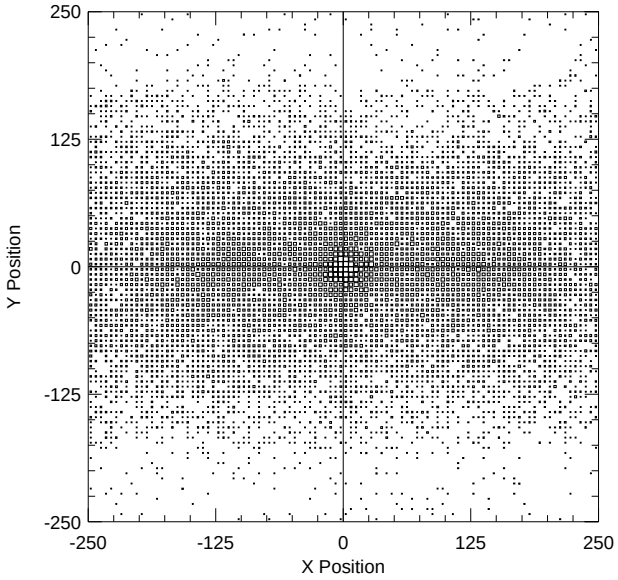
# Location for TOF

ROSY magnet gives a similar feature for the tracks:

After ROSY



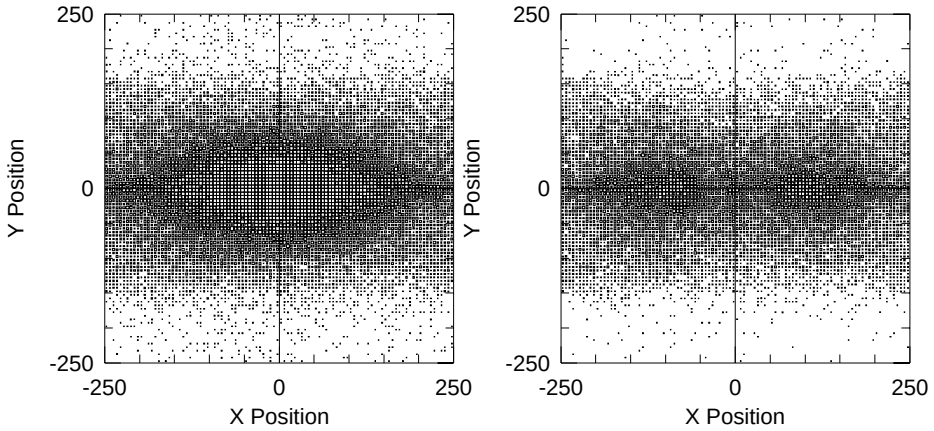

Before ROSY



# Location for TOF

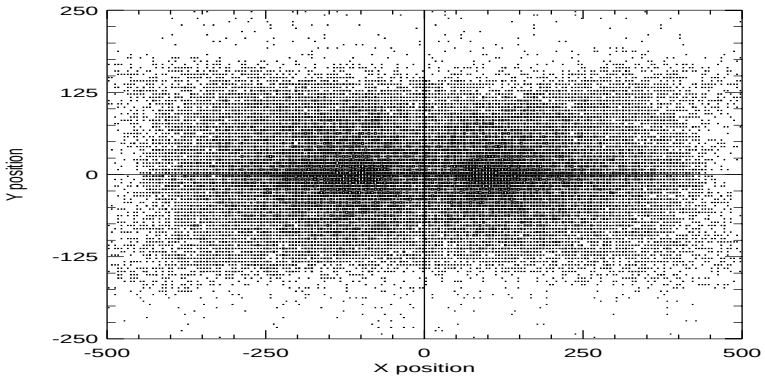
Lets look before the second magnet: (−251 cm)

All Tracks




TOF momentum range

Clearly there are two peaks due to the JGG magnetic field when looking at the restricted momentum.




The tracks go out for a large area in X

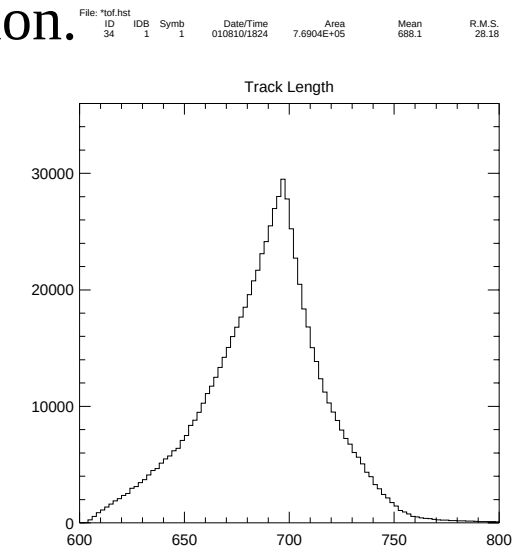
78% within ± 250cm

Full area about 9m x 3m

# Time Resolution

T0 information:

Assumed to come from a TOF counter in the beamline.
Should be small and have very good timing resolution.




Path Length:

Tracks have different path lengths from the primary interaction which effects the final time value observed. For comparison we normalize to 700cm flight distance.

Estimating the final resolution of the system:

$$T = \left(\left(T_d + G_1 * R_d\right) - \left(T_0 + G_2 * R_0\right)\right) * \left(700cm/s\right)$$

G's are Guassian random numbers
T's from GEANT and R's are the resolutions



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# Time Resolution

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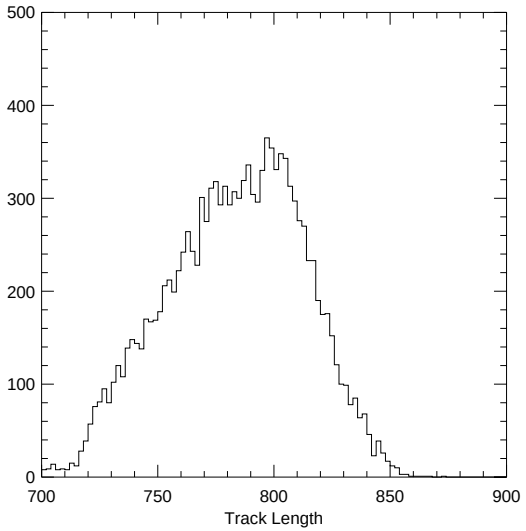
Path Length:

Tracks have different path lengths from the primary interaction which effects the final time value observed. For comparison we normalize to 700cm flight distance. Minimum Distance with ROSY




Estimating the final resolution of the system:

$$T = \left( \left( T_d + G_1 * R_d \right) - \left( T_0 + G_2 * R_0 \right) \right) * \left( 700cm/s \right)$$

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# Time Resolution

Assuming 100ps resolution for both T0 and detector:

Black is pions
Red is kaons
Blue is protons

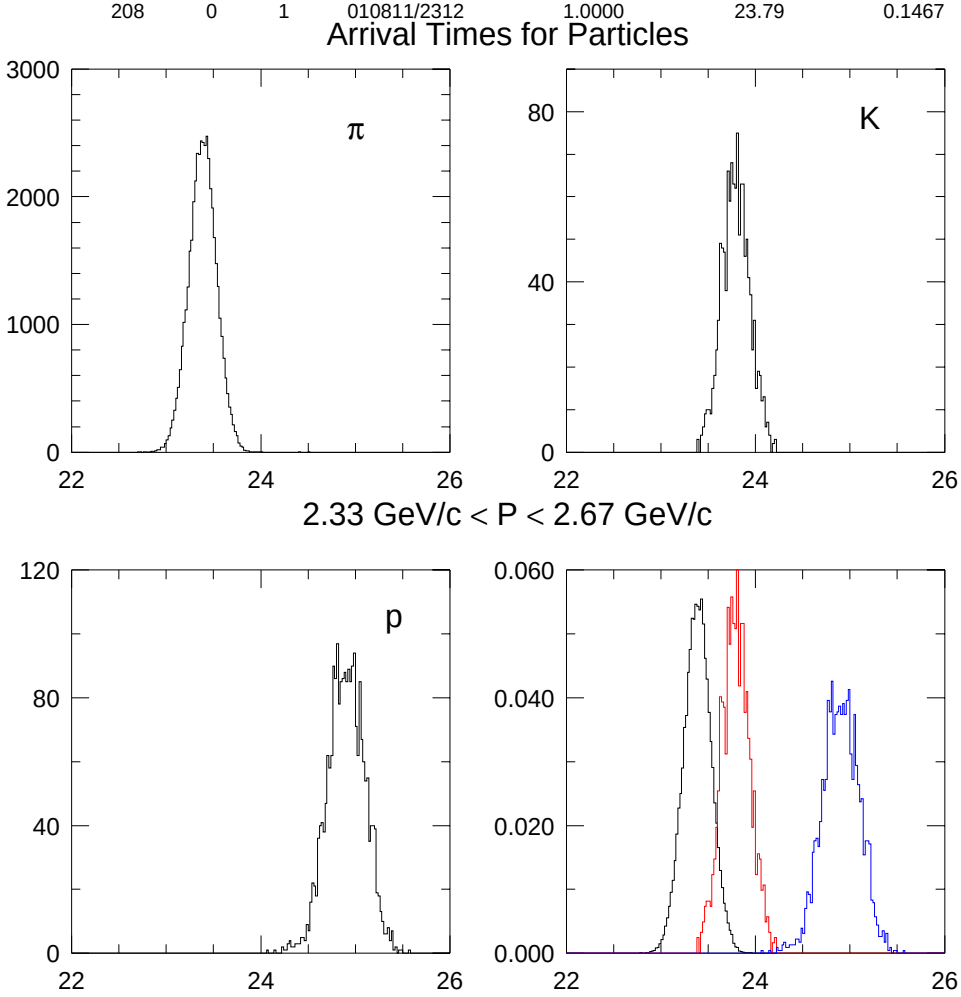
Note most of the tracks hitting the TOF plane are
pions: 44,589
kaons: 1,200
protons: 2,275

Resolutions: ~ 146ps
protons: ~200ps

The last plot is normalized to unit area for all three.

File: *tof.hst

| ID | IDB | Symb | Date/Time | Area | Mean | R.M.S. |
|---|---|---|---|---|---|---|
| 34 | 108 | 1 | 010811/2311 | 4.4589E+04 | 23.39 | 0.1466 |
| 34 | 208 | 1 | 010811/2312 | 1219. | 23.79 | 0.1467 |
| 34 | 308 | 1 | 010811/2311 | 2275. | 24.90 | 0.1968 |
| 108 | 0 | 1 | 010811/2312 | 1.0000 | 23.39 | 0.1466 |
| 208 | 0 | 1 | 010811/2312 | 1.0000 | 23.79 | 0.1467 |

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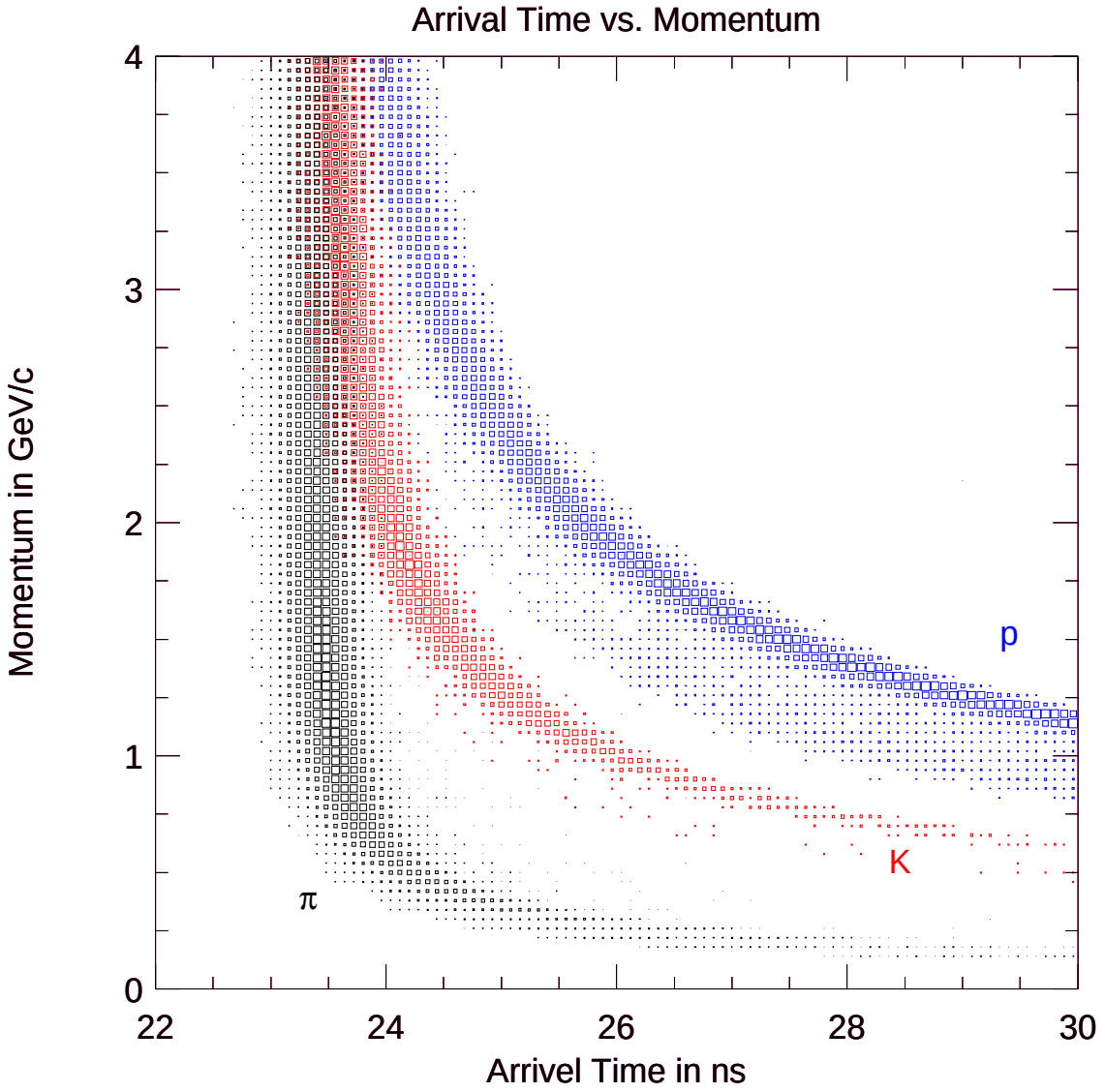
# Time Resolution vs. Momentum

Now we look at these as a function of the track momentum.

Above 3GeV there is virtually no separation between K's and π's

100ps resolution for both times is assumed



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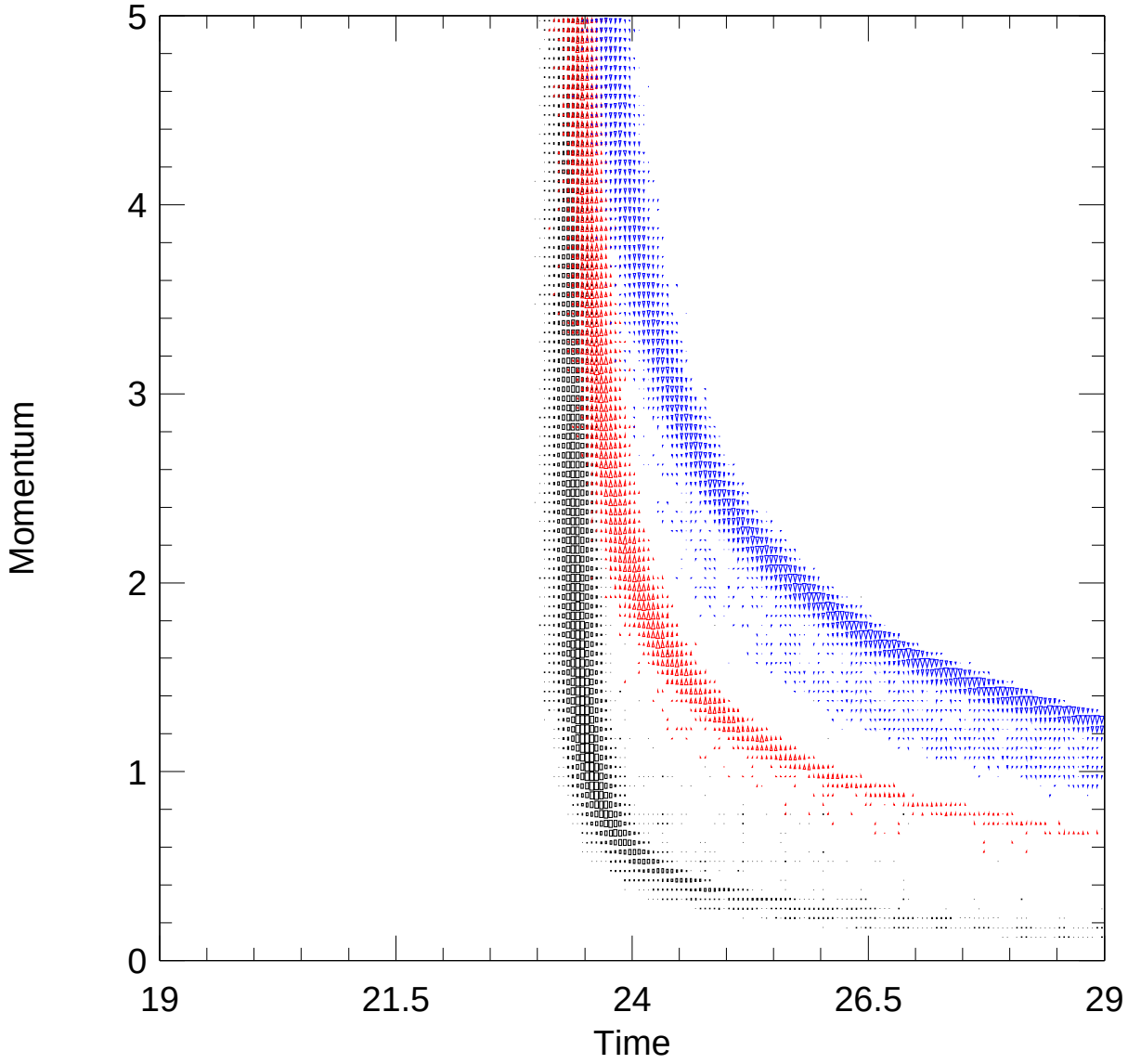
# Time Resolution vs. Momentum

What can we do if we have better resolution:

80ps resolution on TOF and 40ps resolution on the $T_0$

Clearly better separation at 2.7 GeV and below



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# Time Resolution Summary

| Momentum (GeV/c) | Resolution 50ps | 100ps | 150ps | 0ps,100ps | 50ps,100ps | 0ps,150ps | 50ps, 150ps | 40ps,80ps | 50ps,200ps |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 - 1.33 | 5.3 | 4.7 | 4.0 | 5.1 | 5.0 | 4.7 | 4.6 | 5.2 | 4.2 |
| 1.33 - 1.67 | 5.6 | 4.1 | 3.1 | 5.0 | 4.7 | 4.0 | 3.8 | 5.2 | 3.2 |
| 1.67 - 2.0 | 5.4 | 3.3 | 2.3 | 4.4 | 4.0 | 3.2 | 3.0 | 4.7 | 2.4 |
| 2.0 - 2.33 | 4.4 | 2.5 | 1.7 | 3.5 | 3.1 | 2.4 | 2.3 | 3.8 | 1.8 |
| 2.33 - 2.67 | 3.6 | 2.0 | 1.3 | 2.7 | 2.4 | 1.8 | 1.8 | 3.0 | 1.4 |
| 2.67 - 3.0 | 2.9 | 1.5 | 1.0 | 2.1 | 1.9 | 1.4 | 1.4 | 2.4 | 1.1 |

.1

Table 1: Separation achieved for various timing resolutions. When there are two resolution values given, the first is the beam resolution and the second is the detector resolution. If only one resolution is given, it is assumed for both. The values in the table are separations given in terms of sigmas as described in the text.

In all the cases above, the separation is calculated as:

$$\sigma = \frac{\Delta Mean}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

Recall the Cherenkov detector threshold for pions is 2.7 GeV/c

# Segmentation of the TOF wall

Average number of tracks hitting the wall: (5m wide cave)

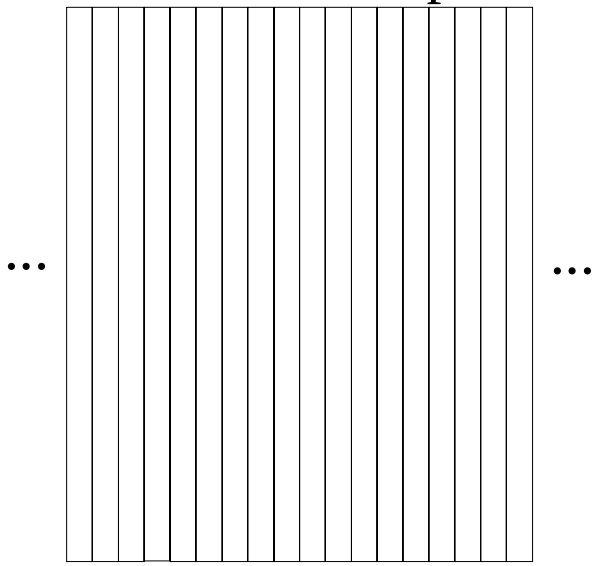
pp collisions: 7.4 / 2.2 in TOF momentum range

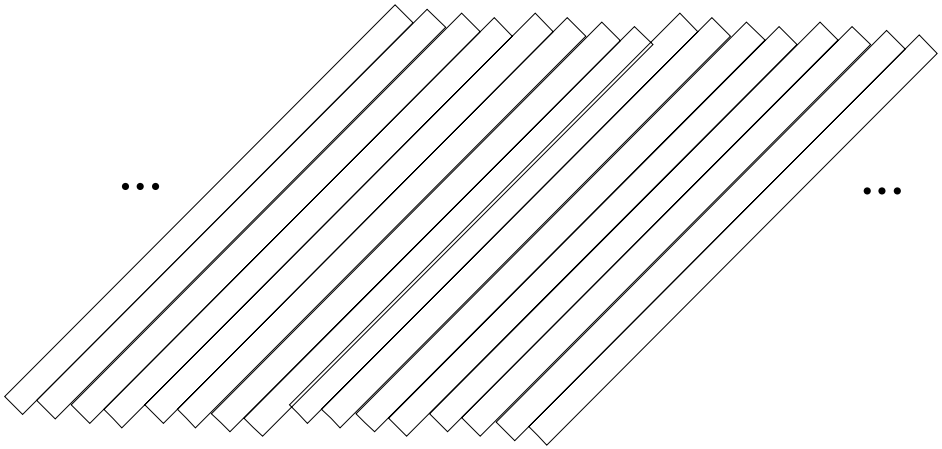
MINOS target: 11.2 / 5.3 in TOF momentum range

Need to have only one hit per counter to be sure we obtain a good measurement of the time of flight

Segment the detector: Strips? Tiles?

Width of strips? Angled at $45^0$ ?





# Segmentation of the TOF wall

MINOS TARGET:

Using counter at Z = − 251cm we get efficiencies of:

| | | | |
|---|---|---|---|
| 10cm wide X | 76.9% | 5cm wide X | 86.9% |
| 10cm wide Y | 53.7% | 5cm wide Y | 69.7% |
| 10cm wide U/V | 71.5% | 5cm wide U/V | 83.4% |

What if we try two planes:

| | | | |
|---|---|---|---|
| 20cm wide XY | 73.6% | 10cm wide XY | 87.9% |
| 20cm wide XU | 77.2% | 10cm wide XU | 90.2% |
| 20cm wide UV | 78.0% | 10cm wide UV | 89.7% |

Efficiency is defined as a TOF hit in a counter with no other hit in that counter. These values are only for tracks with momentum between 0.7 GeV/c and 2.7 GeV/c

All tracks hit the TOF wall within +/− 250cm of beamline in X,Y

Two dimensional tilling with about 100 counters runs about 82% with symmetric tilling and with more tiles around the peaks.



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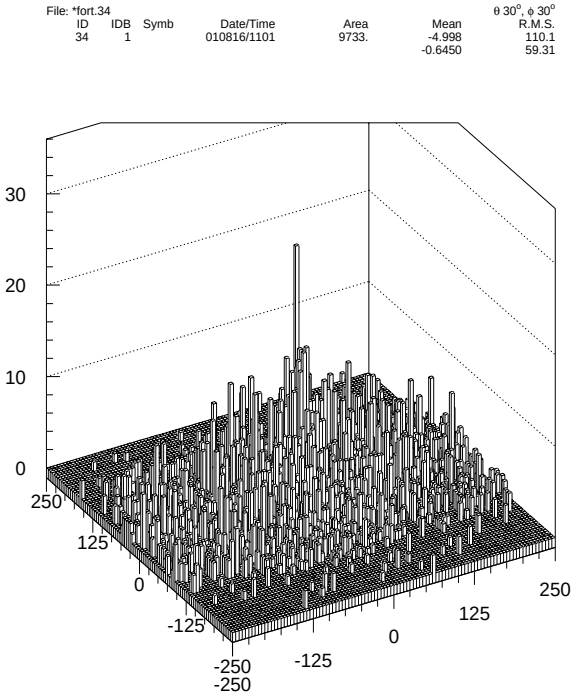
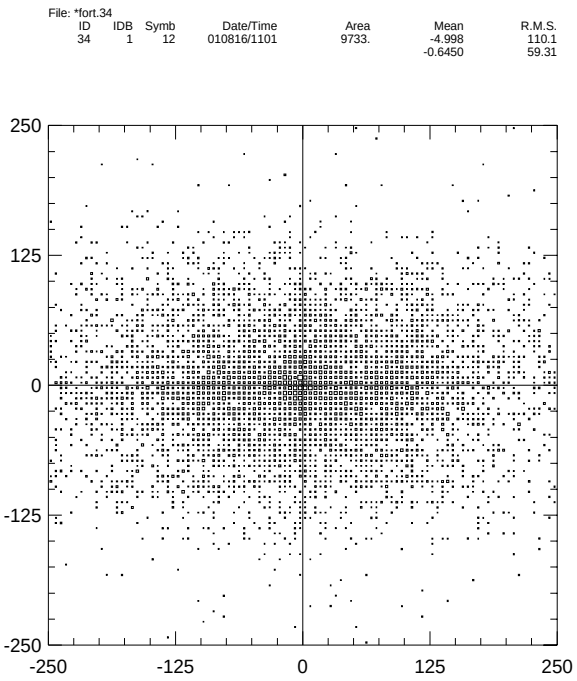
# Segmentation of the TOF wall

We can see that the hits for TOF momentum particles are spread out over the wall with some peaking in the center. It is a very broad peak.



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# Time of Flight Summary

If we want to obtain 3σ separation of K/π for tracks up to 2.7 GeV/c
the resolution needs to be 40ps on $T_0$ and 80ps on TOF counter
50ps resolution needed to get to 3.0 GeV/c

A lower time resolution will not give this separation. At 100ps on the counter we only get 2.4σ separation

Segmentation of the TOF wall will require 5cm strips or two layers to obtain good efficiency.

A two layer wall, doubles cost of scintillator but gives two time measurements for some tracks ( 60% with XU 10cm strips)

Cost likely to be a big issue as to what can be built.



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# Other TOF systems

E802 at Brookhaven: NIM A 290 (1990) p41.

- Material: 160 BC 404 strips
- Size: 78cm x 1.6cm x1.6cm
- Resolution: 75ps

CLEO NIM A 320 (1992) p66.

- Material: 64 BC 408 strips
- Size: 10cm x 5cm x 280cm
- Resolution: 139ps for Bhabhas , 154ps for hardens

CIF www−cdf.fnal.gov/upgrades/PAC/p909.ps

- Material: 216 BC 408 strips
- Size: 4cm x 4cm x 300cm
- Resolution: about 100ps
- Total Cost: $1,027,145



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# The COST

| | | | |
|---|---|---|---|
| Scintillator: | BC 408 | 10cm x 6cm x 300cm | $1325 each |
| | BC 420 | 10cm x 6cm x 300cm | $1700 each |
| | EJ−200 | 10cm x 6cm x 300cm | $1130 each |

| | | | |
|---|---|---|---|
| Phototubes: | Hamamatsu | 2" | $855 − $1400 each |
| | | 3" | $1650 each |

Electronics:

| | |
|---|---|
| HV | From Prep? |
| ADC | From Prep? |
| TDC | Phillips: $180/channel −− From Prep? |

Outstanding questions:

Liquid Scintillator? Used Phototubes?

Other Technologies?



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